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(54) A method and apparatus for the diagnostic testing of electrical equipment of a vehicle.

(57) A method is described for the integrated diagnostic testing of the electrical equipment for the starting and power supply of a vehicle. The diagnostic testing is carried out on the components installed in the vehicle and mutually connected in an operative manner, and the intervention of each of these components in starting the vehicle is verified, taking into account the mutual iterations which modify the nominal characteristics. The method thus comprises verifying the state of charge and wear of the batteries (1, 2), the serviceability of the starter motor (4) on the basis of the condition of the batteries, the intervention of the alternator (5) and the regulator (9), and determining the minimum temperature at which it is certain that the vehicle will start with the batteries being tested.

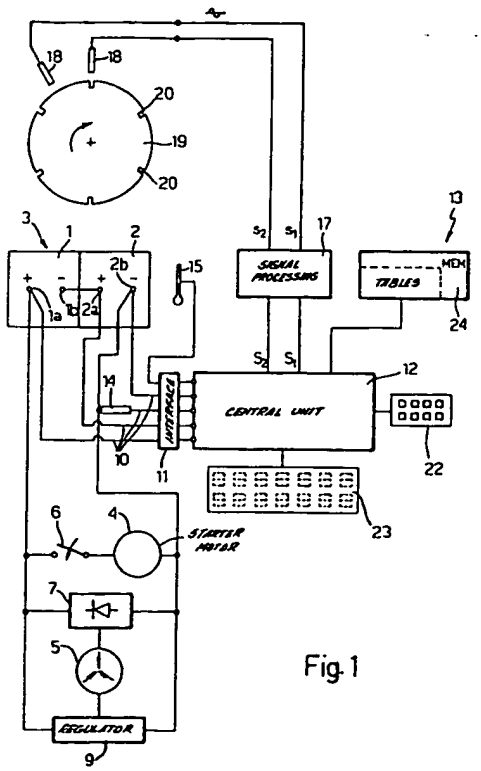

Fig.1

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The present invention relates to a method and apparatus for the diagnostic testing of the electrical equipment of a motor vehicle, such as the batteries, starter motor, alternator and regulator.

Various procedures have been developed in motor vehicles for the diagnostic testing of the operation of the devices serving for the starting and power supply of the vehicle itself. These procedures generally necessitate the dismounting of the device to be tested and its connection to apparatus for measuring appropriate electrical quantities of the device itself. Firstly, this approach involves considerable operations for dismounting and connecting the devices and, above all, does not make it possible to obtain completely reliable results in respect of the actual serviceability of the devices in the operative condition, in view of the fact that the devices themselves are tested one at a time and it is not taken into account how the less than perfect behaviour of each component influences the other components of the electrical system.

Therefore, the object of the present invention is to devise a diagnostic method and apparatus which make it possible to verify the actual serviceability of the electrical equipment, thereby obviating the disadvantages and limitations of known systems.

Accordingly, the present invention provides a method for the diagnostic testing of the electrical equipment of a motor vehicle, comprising at least one battery, a starter motor, an alternator and a regulator, characterised by verifying the serviceability of said devices in an integrated manner, measuring characteristic parameters for each device during their operation while installed on the vehicle and comparing the measured characteristic parameters with theoretical characteristic parameters calculated on the basis of the state of serviceability of at least one of the other devices.

With a view to a better understanding of the invention, a preferred embodiment thereof will now be described below, non-restrictively by way of example, with reference to the accompanying drawings, wherein:

- Figure 1 shows a block diagram of the diagnostic apparatus connected to the devices to be tested;
- Figures 2 to 6 are flow diagrams relating to the other components of the electrical system.
- Figure 7 shows the behaviour of electric signals taken from the diagram in Figure 1;
- Figure 8 is an equivalent diagram of the circuit for measuring various parameters of the batteries, and
- Figures 9 to 14 illustrate characteristic curves relating to the devices to be tested.

Referring now to Figure 1, the drawing shows two batteries 1 and 2 mutually connected in series and each provided with a pair of terminals 1a, 1b and 2a, 2b, respectively positive and negative. In the following description the assembly of the two batteries is frequently designated as a single battery 3 having terminals 1a and 2b. Both a starter motor 4 and an alternator 5 are connected in parallel with the battery 3. A switch 6 operated by the starting key of the vehicle (not shown) is provided in series with the motor 4 and the alternator is connected to a rectifier 7. A regulator 9 is provided to maintain the batteries under a constant charge and it regulates the current supplied by the alternator 5 to the batteries themselves, on the basis of the voltage present between the terminals 1a and 2b.

Leads 10 connect the terminals 1a, 2a and 2b to an interface 11 which, in turn, is connected to a central unit 12 of the diagnostic apparatus according to the invention, which is generally indicated by the reference numeral 13. Additionally, the central unit 12 is connected via the interface 11 to an ammeter connection 14 serving to measure the current supplied or absorbed by the batteries. Advantageously, to enable the ammeter connection 14 to be used for measuring both the direct current, delivered by the batteries, and the reverse current, absorbed by them (while being charged by the alternator), the "offset" voltage of the ammeter is set to a value such that the maximum value expected for the reverse current corresponds to a zero output voltage.

The central unit 12 is additionally connected, via the interface 11, to a thermometer 15 for temperature measurement and, via a signal-processing unit 17, to a pair of sensors 18 provided in the vicinity of the engine flywheel 19. The sensors 18, which are preferably of the inductive type and are spaced apart from one another at a predetermined angle of 12-24° for example, detect the passing of notches 20 provided accordingly on the periphery of the flywheel 19 and spaced apart at a predetermined angle, for example 60°.

The central unit 12 is also connected to input/output units, typically a keyboard 22 and a display unit 23, as well as a memory, including tables relating to the typical parameters and characteristics of the different electric devices to be tested.

The diagnostic method according to the invention will now be described with reference to Figures 2-6. The purpose of this diagnosis is to test the starter motor, alternator, voltage regulator and batteries in an integrated manner, i.e. under conditions which entirely correspond to those of actual operation, adapting the respective characteristics to the operating conditions of the other components so as to indicate any anomalous conditions which prevent the correct operation of the various devices under

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the actual running conditions of vehicle. Furthermore, the investigation also has the aim of indicating the minimum temperature below which it is not certain that the vehicle will start.

The initial stage comprises verifying the state of charge and wear of the battery, which can be carried out in any known manner. Suitably, it is possible to utilise the procedure described in Italian patent application TO91000827, filed on the 31.10.1991, in the Applicant's name and which will be briefly described below for reference purposes.

Referring now to Figure 2, starting from block 30, the diagnostic apparatus 13 is connected to the battery 3 in the manner shown in the diagram of Figure 1. (In this stage, the testing of the batteries 1 and 2 can be carried out jointly, by evaluating all the characteristics of the assembly of the two batteries, as described, or the investigation can be carried out on each battery 1, 2, by measuring the characteristics of each battery separately so as to indicate the state of charge and wear of each of them). Accordingly, using the keyboard 22, the operator enters the data (for example the initials) relating to the electrical components which are to be tested, block 31, and, with the engine switched off, the system measures the actual internal resistance RI of the battery 3 (sum of the resistance values of the batteries 1 and 2), block 32. Said measurement can be carried out using any known procedure and, therefore, it will not be described. The temperature T of the battery is then measured, block 33, and the internal resistance just measured is standardised at the temperature of 25°C on the basis of the equation:

$$RI_N = RI / [I-K(T-25)], \quad (1)$$

in which $K=0.002531$ ($°C^{-1}$), block 34. Subsequently, the no-load voltage V of the battery 3, which is a function of the state of charge, block 35, and the theoretical internal resistance RI_t is calculated, block 36, which corresponds to the state of charge detected. For this purpose, the following algorithm is accordingly utilised, valid experimentally:

$$RI_t = K_1 + K_2 * V$$

in which $K_1 + K_2$ are parameters dependent on the batteries
under consideration and are stored in the memory 24.

Subsequently, on the basis of the deviation present between the actual internal resistance and the standardised theoretical internal resistance, and on the basis of the value of the no-load voltage V (depending, as already stated, on the state of charge) it is possible to establish whether or not the battery is serviceable or whether superficial charges are present which do not allow the condition of the battery to be reliably determined, block 37. If it is established that the batteries are worn, a message is displayed indicating that replacement of the batteries is required (block 39) and the test ends; however, it is established that the batteries are discharged, the appropriate message is displayed (block 38) and the test ends. If any doubt exists or in the case of a positive result of the preceding test, the system proceeds with the subsequent test stages, as described in detail in Figures 3-6.

In particular, if the result of the preceding test is uncertain owing to the presence of superficial charges, there are carried out in succession: the test on the starter motor (block 40) described in detail in Figure 3, the test on the alternator and on the regulator (block 41) described in detail in Figure 4, the second part of the test on the batteries (block 42) described in detail in Figure 5, and the third part of the test on the batteries (block 43) described in detail in Figure 6. However, if the preceding test on the batteries provided positive results, there are carried out in succession: the test on the starter motor (block 40), the test on the alternator and on the regulator (block 41) and the third part of the test on the batteries (block 43), after which the procedure ends.

The starter motor test procedure will now be described. This procedure, which is carried out while the vehicle is being started, is based on a comparison between the characteristics measured and those which said motor should have depending on the general state of the batteries, since the characteristic of the starter motor depends on the condition in respect of charge and wear of the batteries supplying power to it. Therefore, according to the invention, the characteristic of said motor is formulated as a function of the maximum current which can be delivered by the batteries, as derived from the internal resistance of the batteries (including the resistance of the motor itself and the wiring). In this stage, the voltage taken as a reference for calculating the maximum current delivered cannot be that measured at the battery terminals, in that it is affected by the superficial charges, and it has to be calculated analytically, as will be described below with reference to Figure 3.

In detail, firstly a message is generated for the operator to start the vehicle (block 45). Subsequently, block 46, there are acquired the values of the voltage present between the battery terminals 1a and 2b and of the current delivered by the batteries themselves, as well as the temperature T and the time Dt elapsed between two pulses originating from the sensors 18. In fact, as indicated, upon detecting the passing of a notch 20 on the

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flywheel 19, each sensor generates a substantially sinusoidal pulse. The train of sinusoidal pulses, forming the signals s_1 and s_2, is fed to the circuit 17 which generates the digital signals S_1, S_2 shown in Figure 7. From each digital signal S_1, S_2 the first pulse detected at the start of flywheel rotation is rejected (since it is disturbed to a greater extent) and the current and voltage values are stored which are measured at the battery in the time interval between the second pulse of the signal S_1 (with leading edge at the instant t_1) and the third pulse of the S_2, with trailing edge at the instant t_2). The time interval Dt between the two pulses under consideration is also measured, which corresponds to the time required by the flywheel to rotate through a given angle.

Subsequently, block 47, the average number of revolutions N_{AV} of the starter motor and the average current I_{AV} in the interval in question are calculated, as is the internal resistance R_i of the battery and the reference voltage V_{REF}. In particular, the number of revolutions N_{AV} is calculated by determining the number average number of revolutions in the interval Dt and then said average value is multiplied by the mechanical ratio between the starter motor pinion and the flywheel. However, R_i and V_{REF} are calculated using the equivalent circuit shown in Figure 8, in which the batteries 1, 2 are each represented by a voltage generator E_1, E_2 and by a resistor R_1, R; the resistor R_c represents the resistance of the wiring system (cables) and R_M represents the resistance of the starter motor.

In this circuit the voltage V between the terminals 1a and 2b is given by:

$$V = E_1 + E_2 - (R_1 + R_2) * I,$$

where I is the current delivered by the batteries. By defining

$$R_i = R_1 + R_2 \text{ and } V_{REF} = E_1 + E_2,$$

there is given:

$$V = V_{REF} - R_i * I.$$

By designating V', I', and V'', I'' the current and the voltage of the batteries detected at the instants t_1 and t_2, there is given:

$$V' = V_{REF} - R_i * I'$$
$$V'' = V_{REF} - R_i * I'';$$

from which, by simple calculation,

$$R_i = (V' - V'')/(I'' - I')$$
$$V_{REF} = (I'V'' - I''V')/(I' - I'').$$

Successively, block 48, the total resistance R_{TOT} of the circuit in Figure 8 is calculated,

$$R_{TOT} = R_i + R_c + R_M,$$

in which R_M and R_c are known from experimental measurements under stalling conditions and are compensated for in temperature).

Subsequently, the maximum current available $I_{MAX} = V_{REF}/R_{TOT}$ is calculated, block 49, and the theoretical characteristic of the starter motor in question is formulated on the basis of the condition of the batteries, block 50.

In fact, for each starter motor there is a family of curves each representing the relationship between the absorbed current and the number of revolutions for a different condition of the batteries supplying power to said motor, as shown in Figure 9, which represents three curves relating to the same motor; in particular, the curve C_1 is that corresponding to the connection to a battery in optimum condition, whereas the curves C_2 and C_3 are the characteristics relating to batteries in a less than optimum condition. In these curves, the maximum current absorbed corresponds to a condition at zero revolutions (stalling current) and therefore, knowing the maximum current I_{MAX} which can be delivered by the battery, it is possible to determine which one of the characteristics is applicable in the case being tested.

However, the procedure just described necessitates the storing of a high number of curves and, therefore, in initial approximation, with a view to reducing the number of curves stored in the system, it is possible, for example, to derive the applicable curve in the case being tested by shifting the curve corresponding to the theoretical operation of the motor, with batteries in optimum condition (curve C_1 in Figure 9), until encountering the x-axis at the point I_{MAX} just determined, the point at the infinity of said curve, placed on the y-axis, being maintained fixed. This procedure is shown in Figure 10, in which are plotted the curve C_1 under theoretical operation and the shifted curve C_T obtained in the manner described. Therefore, this solution makes it possible to store only one characteristic for each type of starter motor and to derive the curve in each case formulated on the basis of the condition of the batteries, with a substantial memory saving.

Subsequently, block 51, it is evaluated whether the operating point P, which has as co-ordinates the previously calculated values in respect of current and number of revolutions I_{AV}, N_{AV}, is situated in the vicinity of the shifted curve C_T and specifically within a predetermined tolerance, as indicated schematically in Figure 10 by the hatched zone delimited by the curves in chain line defining the

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tolerance limits. If the point P is situated below the tolerance range, output NO from the block 52, it means that there are electrical problems caused, for example, by wear in the brushes, in which case the system generates an appropriate message (block 53) and terminates this test stage. If the point P is situated above the tolerance range, output YES from the block 52, it means that a short-circuit has occurred between the windings, in which case the system generates a corresponding message (block 54) and terminates this diagnostic stage.

However, if the point P is situated within the tolerance range, as in the example shown in Figure 10, it is still necessary to verify whether the relationship between the number of revolutions and current corresponds approximately to that expected. For this purpose, as indicated by block 56, the current I_A is determined which the motor should absorb, under correct conditions, at the temperature prevailing during the test. Said value is read from an experimental graph illustrated in Figure 11 and representing the relationship between the absorbed current and the temperature for a given motor and a given pair of batteries. Said graph is stored in tabular form in the memory 22. On the basis of the value I_A there is determined, on the formulated or shifted curve C_T obtained previously, the expected operating point P_A, as shown in Figure 12, block 57. Subsequently, the previously determined actual operating point P is compared with the expected point P_A,block 58. If P is situated in the vicinity of P_A, this means that the starter motor is in perfect operating condition, then the system generates a corresponding message, block 59, and ends this diagnostic stage. Otherwise, a problem of mechanical origin has arisen, for example caused by worn bushings or the disengagement of the coupling gears between the starter motor pinion and the flywheel. In this case a suitable message is generated for the operator, block 60, and this diagnostic stage ends.

With reference to Figure 4, the analysis of the alternator is based on a comparison between the characteristic applicable to an alternator in perfect operating condition and the curve which can be obtained from measurements taken from the alternator being tested. For this purpose, block 65, the system provides for the acquisition of the values for the current fed to the batteries when the number of revolutions N of the engine flywheel, detected by way of the sensors 18, is within the range 400-1500 rpm, i.e. before the regulator intervenes, thus limiting the current delivered by the alternator. Specifically, the system provides for the detection of the pairs of values, number of revolutions/current delivered, for the purpose of determining the curve described by the relationship present between these two quantities for the alternator being tested. The curve just obtained is then compared with the characteristic curve, as illustrated in Figure 13. In this Figure, the curve B in solid line represents the ideal characteristic for the model of alternator in question, and the curves B_1-B_3 represent curves plotted on the basis of measurements in three different cases of alternator malfunction. The comparison between the characteristic curve B and that actually measured, block 66, may give the following results: substantial coincidence between the two curves (with a tolerance of 10%, for example); measured curve reduced with respect to the theoretical curve but having similar behaviour; measured curve which initially follows the theoretical curve but then deviates therefrom (lower value for the maximum current which can be delivered); measured curve having maximum current delivered higher than that of the theoretical curve.

The first case (substantial coincidence) indicates satisfactory alternator operation; the second case (measured curve reduced but with similar behaviour, as shown by the curve B_1 in Figure 13) indicates the presence of a short-circuit between the alternator windings; the third case (initially correct curve but the maximum current which can be delivered of a lower value than the theoretical value, as by the curve B_2) is indicative of a mechanical problem, for example that the belt is slipping; the fourth case (measured curve higher than the theoretical curve, curve B_3) is caused by the fitting of a rotor not conforming to specification. In all cases, the system generates a message corresponding to the situation detected (blocks 67-70) and proceeds with the testing of the regulator.

To analyse the regulator, it is simply verified that it intervenes correctly so as to limit the current delivered to the batteries by the alternator when the voltage obtained at the batteries exceeds a predetermined threshold, in accordance with the characteristic indicated in Figure 14. In this Figure there is indicated the behaviour of these two quantities as a function of the state of charge of the batteries; in known manner, when the voltage V reaches a threshold V_{TH}, the current absorbed by the batteries decreases as a result of the intervention of the regulator.

For this purpose, block 73, the system verifies that the vehicle is maintained at a suitable operating condition for testing (typically between 1300 and 1500 rpm), if this is not so it sends an appropriate message to the operator (block 74), otherwise (or after attaining the specified operating condition) it detects the voltage and current values of the batteries, block 75. It then verifies whether the voltage exceeds the predetermined threshold value, block 76. If this is not so, the system verifies whether two minutes have passed from the start of

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monitoring, block 77, and if not it returns to the measuring block 75. If the voltage exceeds the threshold value (output YES from block 76) or if the time provided for the analysis of the regulator (output YES from block 77) has elapsed, evaluation of the last current value I acquired then proceeds. In particular, this stage, which is indicated by block 78, comprises verifying that this last current value corresponds to the maximum value of the current delivered by the alternator, in the event of the voltage not having exceeded its threshold value, or verifying that the last current value acquired is lower than the maximum value (current value in respect of how much the voltage measured was below the threshold). If this comparison has a negative result, a message is generated indicating that the regulator is faulty (block 79), otherwise a correct operation message is generated (block 80) and the regulator test procedure thus ends.

Figure 5 illustrates the second part of the battery test which is carried out only if the first part has provided a doubtful result owing to the presence of superficial charges. To a large extent, the second reproduces the stages provided in the first part of the test (blocks 32-37 in Figure 2), except for the fact that the voltage measurement for determining the state of charge is carried out with the engine running so as to eliminate superficial charges.

In detail, this stage initially comprises measuring the voltages V_1 and V_2 at the terminals of the two batteries 1, 2, after the engine has been maintained at a speed of $N \geq 1500$ rpm, block 85. Subsequently, block 86, the state of charge C% of the batteries is measured, as a function of the voltage previously measured. For this purpose use is made of the voltage behaviour as a function of the percentage of charge, indicated in Figure 14 and suitably tabulated and stored in the memory 22 of the apparatus.

Successively, block 87, the theoretical internal resistance R_{it} of the batteries corresponding to the state of charge just determined is calculated, in accordance with the experimental relationship:

$$R_{it} = K_1 + K_2 * C\%$$

in which $K_1 + K_2$ are parameters which depend on the batteries used (as described in greater detail in Italian patent TO91A000827, on the basis of equations (1) and (2) therein).

Subsequently, a message to switch off the engine is generated and the actual switching-off is awaited, block 88, and then the actual internal resistance R_i of the batteries is measured, block 89, in an analogous manner to that described for block 32. The temperature T of the batteries is then measured, block 90, and the internal resistance just measured is standardised at the temperature of 25°C on the basis of equation (1):

$$R_{in} = R_i / [1-K(T-25)],$$

block 91. Subsequently, block 92, the percentage deviation is calculated between the theoretical internal resistance and the measured and standardised resistance, equal to

$$S\% = (R_{in} = R_{it} / R_{it} * 100$$

as described in detail in the above-mentioned Italian patent. This percentage value provides an indication of battery wear and can thus be used for the evaluation of the state of the batteries. In particular, if the deviation thus calculated is greater than a certain threshold value, it is deduced that the batteries are worn and should be replaced. The second part of the battery test thus ends with the display of the state of wear just determined and of the state of charge previously determined, block 93.

The third part of the battery test comprises determining the minimum ambient temperature limit below which it is no longer certain that the vehicle will start. This information is useful, for example, in assessing whether, in their present state, the batteries will last the winter or whether it will be possible to undertake a journey in regions having a more severe climate, or whether it is necessary to replace the batteries.

This procedure is based on a comparison between the power supplied by the starter motor (and proportional to the current absorbed - namely by the torque - and to the number of revolutions, and already determined previously on the basis of the shifted curve) and the power required by the engine to enable it to be started at a given temperature. In particular, to calculate the power required, the current corresponding to the minimum number of revolutions required to guarantee that it will be possible to start the engine is determined. In turn, the minimum number of revolutions to ensure starting is derived from tables obtained experimentally for each engine type, taking into account the type of oil used and the possible presence of auxiliary equipment (for example, a thermal starter).

For this purpose, cf. Figure 6, initially the minimum number of engine revolutions N_{mm} is read from a table, on the basis of data initially entered by the operator and relating to the type of engine in question, block 97. Therefore, by multiplying said value N_{mm} by the mechanical ratio between the pinion and the flywheel there is obtained the minimum number of revolutions N_{ma} of the motor for starting, block 98, and successively, block 99, there is calculated the value of the current I_a ab-

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sorbed by the motor itself in relation to the number of revolutions N_{ma}, using the previously determined shifted curve, as described with reference to Figure 10 (block 50 in Figure 3). The minimum temperature value T_m is then obtained from the current value I_a using the graph shown in Figure 11, block 100. This value does not yet represent the minimum temperature at which starting is assured, since it is calculated using a characteristic which does not take into the variation in electrical characteristics of the batteries at the low temperature just determined. The temperature value just determined is then used to recalculate the power which can be delivered by the motor; however, to reduce the number of iterations required, it is increased by several degrees, for example 5°C (as indicated in block 101).

Successively, block 102, based on the new temperature value T_1, the internal resistance R_{T1} exhibited by the batteries at the temperature T_1 in question is calculated, using the equation (1). From this there is calculated, in the manner already described with reference to blocks 48, 49, the total resistance of the test circuit of Figure 8 at the temperature T_1 and the maximum current I_{T1} which can be delivered under the same conditions. Successively, block 103, on the basis of said current value, the characteristic linking the current absorbed to the number of revolutions of the starter motor is shifted so that the new curve encounters the x-axis in relation to the current value I_{T1} just determined. From the new curve there is determined the current value I_{ma1} corresponding to the minimum number of revolutions N_{ma} to ensure starting previously read from the table, block 104, and the associated minimum temperature T_{m1} is read with reference to the graph in Figure 11, block 105.

Said temperature value T_{m1} is compared with T_1 (block 106) and, if the two values substantially differ, the iteration is repeated, the internal resistance corresponding to the new temperature value being recalculated (blocks 107, 102).

However, if the two values are sufficiently similar the temperature value just determined is displayed, block 108, and represents the the minimum temperature at which the starting of the vehicle is assured with the batteries undergoing testing.

The method and apparatus described thus make possible reliable evaluation of the serviceability of the electrical ignition and power supply devices of a motor vehicle, under conditions which are equivalent to operating conditions, also taking the interactions of the devices themselves into account.

Moreover, the performance of the tests provided does not require the operator to carry out any complicated or protracted operations. In fact, it is only necessary for the operator to connect the apparatus to the batteries and rotation sensors already provided, start the engine and maintain it at the operating speed specified in each case. Furthermore, the control and switching off of the engine may also be carried out automatically, if the vehicle is equipped with electronic control, by way of commands issued by the test apparatus itself.

Finally, the apparatus described makes it possible to obtain a large amount of data regarding the operation of the electrical equipment, including the minimum temperature at which starting is possible.

Lastly, it is evident that modifications and variations can be made to the method and apparatus described and illustrated, without thereby departing from the scope of protection of the present invention. In particular, it is emphasized that the measurement of the actual internal resistance and the calculation of the nominal internal resistance of the batteries can be carried out in accordance with any known method; moreover, the entire stage of evaluating the state of charge and wear of the batteries can be carried out in a different manner to that described, it being a constant factor that the results obtained are used to evaluate the serviceability of the other electrical devices depending on the state of the batteries themselves.

Claims

1. A method for the diagnostic testing of the electrical equipment of a motor vehicle, comprising at least one battery (3), a starter motor (4), an alternator (5) and a regulator (9), characterised by verifying the serviceability of said devices in an integrated manner, measuring characteristic parameters for each device during their operation while installed on the vehicle and comparing the measured characteristic parameters with theoretical characteristic parameters calculated on the basis of the state of serviceability of at least one of the other devices.

2. A method according to Claim 1, characterised by comprising the stages of: determining (50) a characteristic curve correlating the number of revolutions and the current absorbed by said starter motor when connected operatively to said battery, determining (47) the operating point of said motor immediately after starting the vehicle and verifying (51) whether said operating point determined is situated in the vicinity of said characteristic curve.

3. A method according to Claim 2, characterised by comprising a preliminary stage (46-50) for evaluating the state of the battery and for-

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mulating the characteristic curve relating to said starter motor on the basis of said state of the battery.

4. A method according to Claim 3, characterised in that said preliminary evaluating and formulating stage comprises determining (46-49) the maximum current be delivered by said battery under stalling conditions, and determining (50) the characteristic, number of revolutions-current, of said motor having stalling current equal to said maximum current determined.

5. A method according to Claim 4, characterised in that said stage of determining (50) the characteristic comprises shifting a theoretical characteristic for said motor with said battery in optimum condition until it encounters said maximum current determined.

6. A method according to Claim 4 or 5, characterised in that said stage of determining the maximum current which can be delivered comprises a stage of measuring (46) the voltage present at the battery terminals and the current delivered by said battery in two successive instants immediately after the starting of the vehicle, calculating (47) the internal resistance and reference voltage of said battery on the basis of said measured current and voltage values, calculating (48) the total resistance including said battery and determining (49) the maximum current delivered as a ratio between said reference voltage and said total resistance.

7. A method according to any one of Claims 2 to 5, characterised in that said stage of determining the operating point of said motor comprises the stage of measuring (47) the average number of revolutions of said motor and the average current absorbed by said motor immediately after starting said vehicle.

8. A method according to Claim 6 or 7, characterised by detecting pulses (s_1, s_2) generated by at least one rotation sensor (18) mounted on a flywheel (19) of the vehicle, rejecting the first pulse after starting the vehicle and measuring said average number of revolutions and said average current in a time interval between the second and third pulse of said sensor.

9. A method according to any one of Claims 2 to 8, characterised by comprising the stages of determining (46, 56, 57) an expected operating point for said motor and comparing (58) said expected operating point and said determined operating point.

10. A method according to Claim 9, characterised in that said stage of determining an expected operating point comprises the stages of measuring (46) the temperature of the battery, determining (56) a value for the expected absorbed current on the basis of an experimental temperature-current relationship, determining (57) a value for the expected number of revolutions on said characteristic corresponding to said expected current value.

11. A method according to any one of Claims 1 to 10, characterised by comprising a detecting stage (65) for a characteristic curve of said alternator (5) while said battery (3) is being charged.

12. A method according to Claim 11, characterised in that said detecting stage comprises the continuous acquisition (65) of the value for the number of revolutions and the current delivered by said alternator after starting the vehicle within a predetermined range of the number of revolutions of said alternator, and by comprising a comparison stage (66) for said detected characteristic curve with a nominal curve.

13. A method according to any one of Claims 1 to 12, characterised by comprising a stage of determining (75-77) the behaviour of the current absorbed by said battery (3) and the voltage at said battery within a predetermined range of the number of revolutions of an engine flywheel (19) of the vehicle.

14. A method according to Claim 13, characterised in that said stage of determining the behaviour comprises the stages of measuring (75) the voltage at said battery and the current absorbed by said battery when the number of revolutions is above a predetermined limit, and comparing (76) said measured voltage with a threshold value; and also comprising the stage of comparing (78) two values for measured current respectively before and after said voltage has exceeded said threshold value.

15. A method according to any one of Claims 1 to 14, characterised by comprising a stage for determining (97-108) the minimum temperature at which it is possible to start the vehicle on the basis of the battery condition (39).

16. A method according to Claim 15, characterised in that said temperature-determining stage comprises the stages of: determining (102-103)

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the power generated by said starter motor (4) and said battery (3), determining the power (97-99, 104) required for starting an engine of the vehicle at a given temperature and effecting a comparison between said power generated and said power required.

17. A method according to Claim 16, characterised by comprising the stages of: determining (97) the nominal minimum number of revolutions for starting said engine on the basis of experimental values, determining (99) the nominal current absorbed by said motor (4) on the basis of said number of nominal minimum number of revolutions, determining (100) a first minimum temperature value corresponding to the nominal absorbed current, determining (102) an internal resistance value of said battery on the basis of said first temperature value, determining (102) a value for the maximum current which can be delivered by said battery on the basis of said internal resistance, determining (103, 104) a new value for the current absorbed by said motor on the basis of said value for the maximum current which can be delivered, determining (105) a new minimum temperature value corresponding to said absorbed current value.

18. A method according to Claim 17, characterised by repeating the stages of determining (102-107) values in respect of internal resistance, maximum current delivered, current absorbed and minimum temperature on the basis of said new temperature value until attaining (106) two equal temperature values, within tolerance limits, in successive iterations.

19. A method according to Claim 17 or 18, characterised in that, before carrying out said stage of determining (102) an internal resistance value of said battery (3) on the basis of said first temperature value, said first temperature value is increased (101) by a predetermined value.

20. A method according to any one of Claims 17 to 19, characterised in that said stage of determining (99) the nominal current absorbed by said motor is carried out on the basis of a characteristic curve of said motor (4) in the condition connected to said battery (3); in that said stages determining (100, 105) a minimum temperature value are carried out on the basis of experimentally determined ratios, and said stages of determining (104) a new value for the current absorbed is carried out on a characteristic curve (103) formulated on the basis of said value for the maximum current which can be delivered.

21. An apparatus for carrying out the method for the diagnostic testing of the electrical equipment of a motor vehicle, comprising at least one battery (3), a starter motor (4), an alternator (5) and a regulator (9), according to any one of Claims 1-20, characterised by comprising means (12) adapted to verify the serviceability of said devices in an integrated manner, including means adapted to measure characteristic parameters for each device during their operation while installed on the vehicle and to compare the characteristic parameters measured with theoretical characteristic parameters calculated on the basis of the state of serviceability of at least one of the other devices.

22. An apparatus according to Claim 21, characterised by comprising means (12, 15) for measuring the voltage, the current and the temperature of the battery, means (18) for detecting the number of engine revolutions and means (12) adapted to correlate the current and voltage values measured with the number of revolutions and the temperature detected, and to determine actual operating characteristics.

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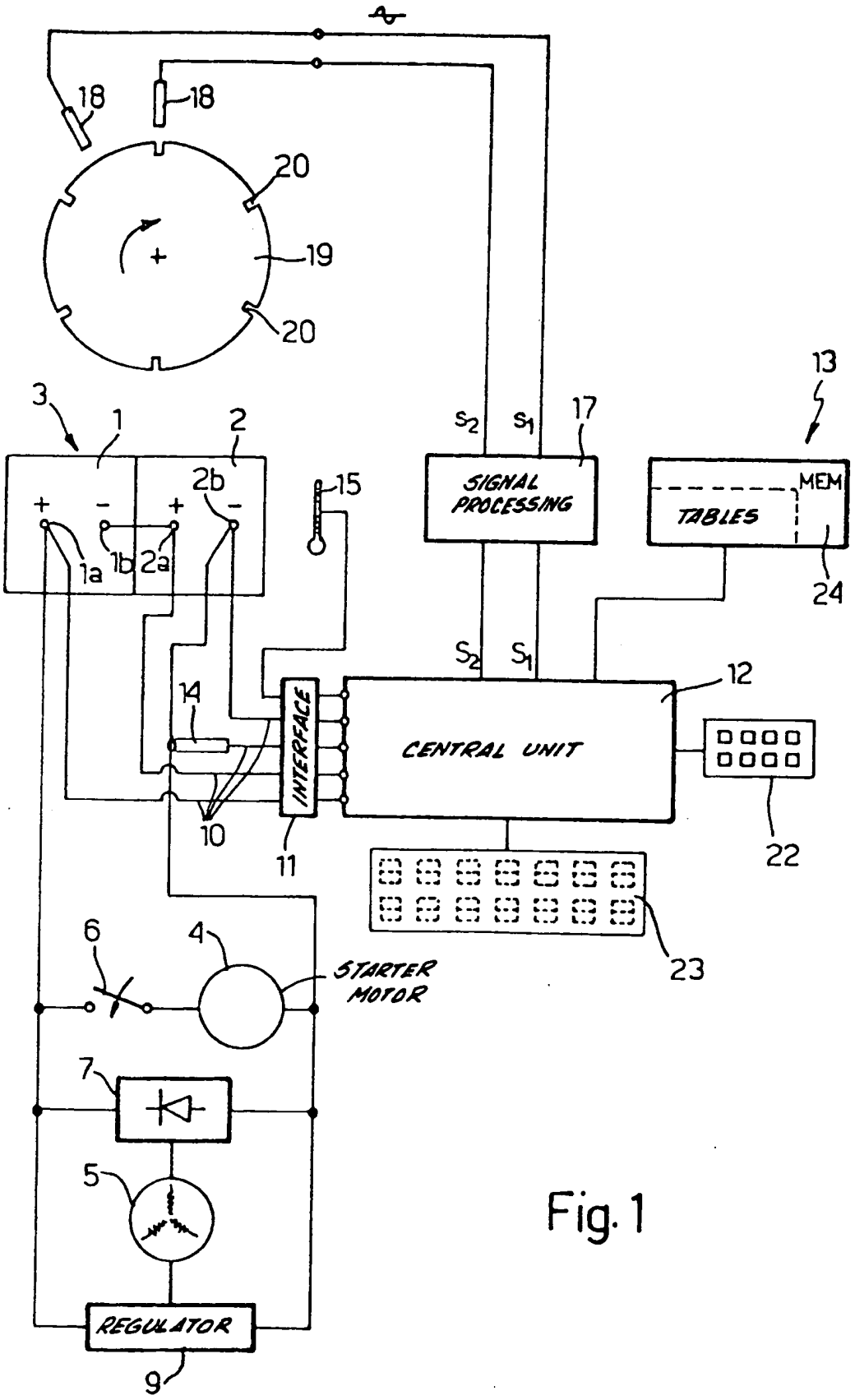
18
18
20
19
20
3
1
2
2b
+
-
+
-
1a
1b
2a
15
S_2
S_1
17
SIGNAL PROCESSING
13
MEM
TABLES
24
S_2
S_1
12
14
INTERFACE
CENTRAL UNIT
10
11
22
23
6
4
STARTER MOTOR
7
5
REGULATOR
9

Fig. 1

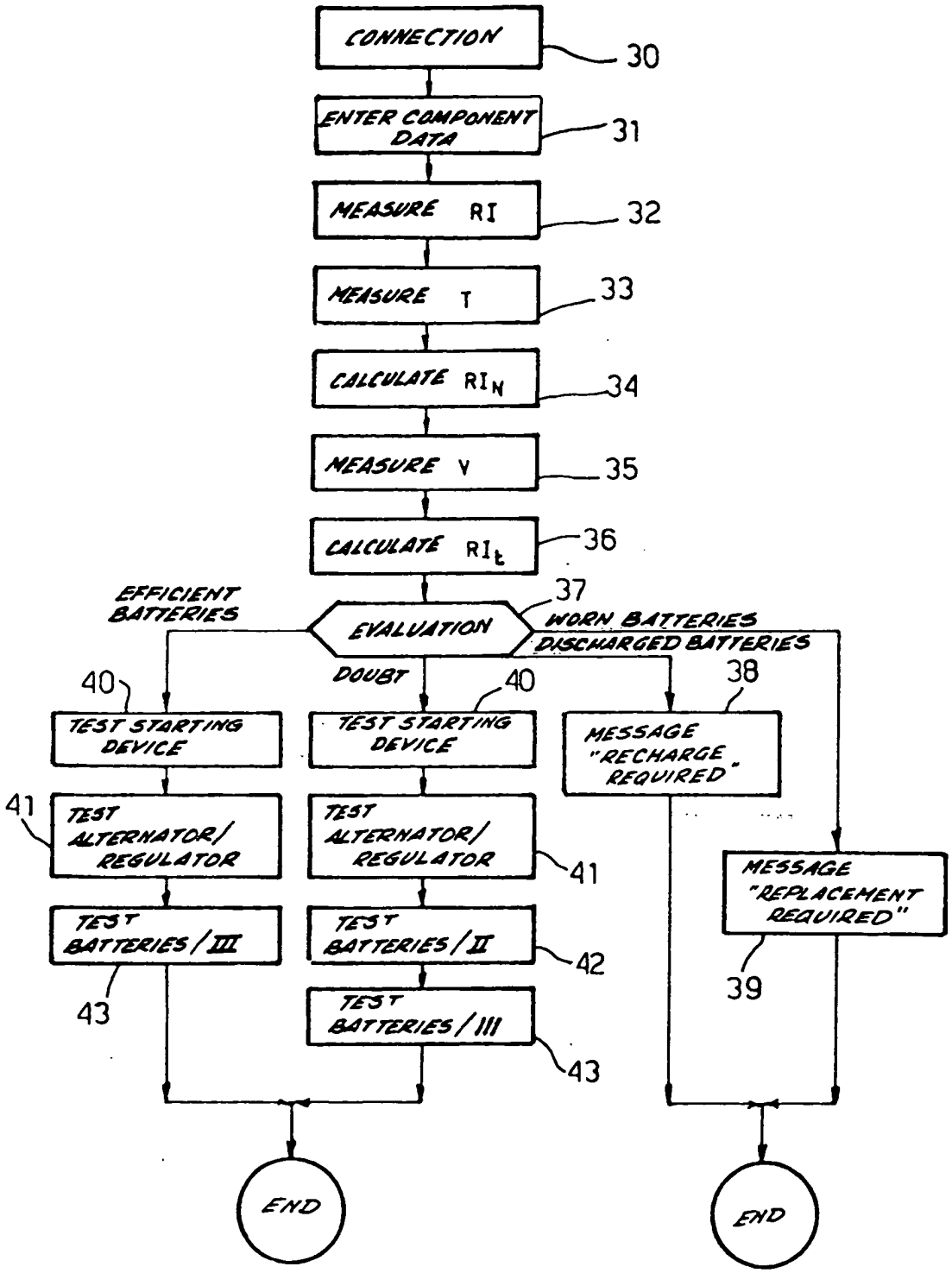
CONNECTION
30
ENTER COMPONENT DATA
31
MEASURE RI
32
MEASURE T
33
CALCULATE RI_N
34
MEASURE V
35
CALCULATE RI_t
36
EVALUATION
37
EFFICIENT BATTERIES
WORN BATTERIES
DISCHARGED BATTERIES
DOUBT
40
40
38
TEST STARTING DEVICE
TEST STARTING DEVICE
MESSAGE "RECHARGE REQUIRED"
41
TEST ALTERNATOR/ REGULATOR
TEST ALTERNATOR/ REGULATOR
41
MESSAGE "REPLACEMENT REQUIRED"
TEST BATTERIES/III
TEST BATTERIES/II
42
39
43
TEST BATTERIES/III
43
END
END

Fig. 2

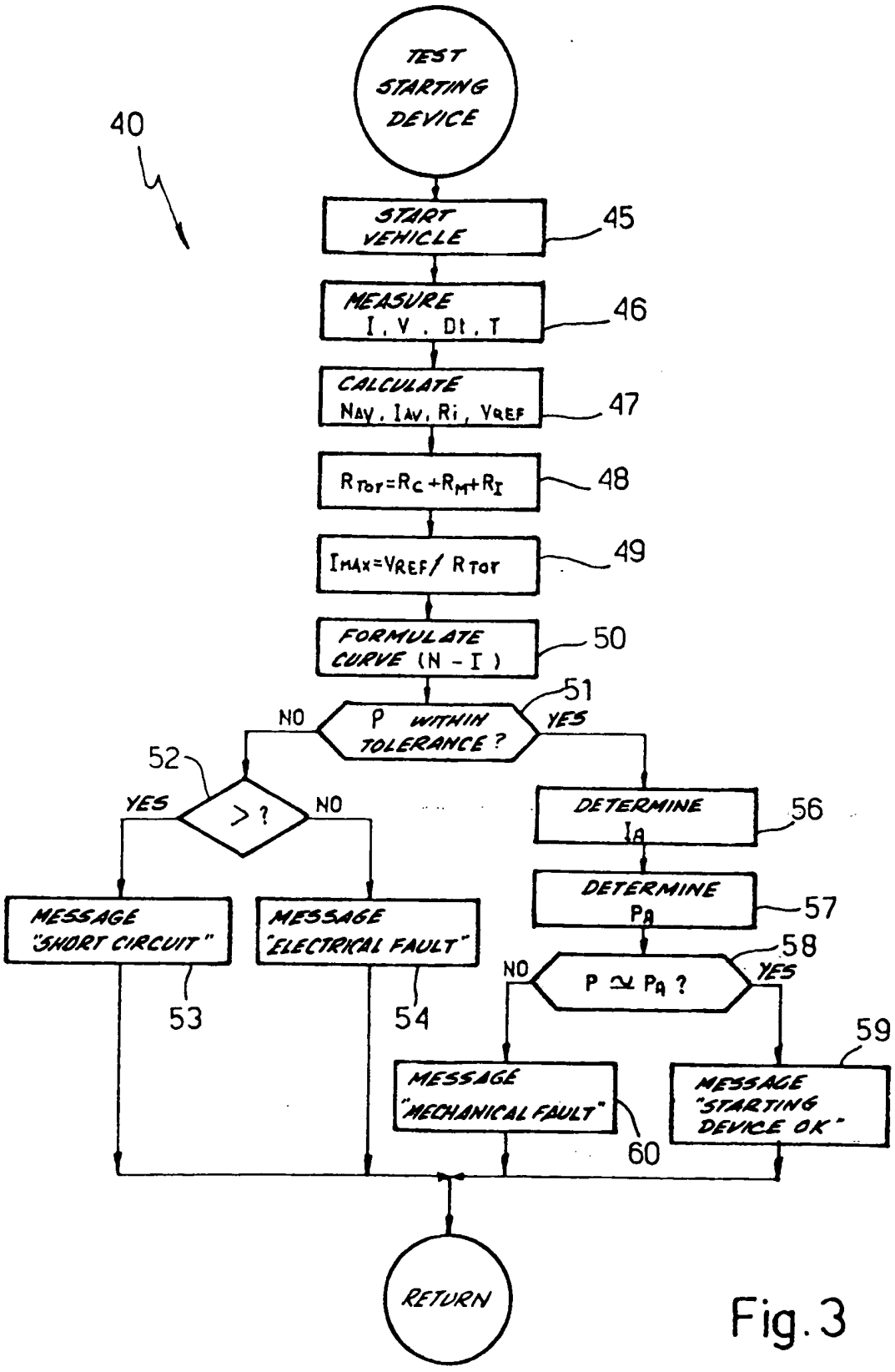
40
TEST STARTING DEVICE
START VEHICLE
45
MEASURE I, V, Dt, T
46
CALCULATE NAV, IAV, Ri, VREF
47
RTOT=RC+RM+RI
48
IMAX=VREF/RTOT
49
FORMULATE CURVE (N-I)
50
P WITHIN TOLERANCE ?
51
NO
YES
52
> ?
YES
NO
MESSAGE "SHORT CIRCUIT"
53
MESSAGE "ELECTRICAL FAULT"
54
DETERMINE IA
56
DETERMINE PA
57
P ≃ PA ?
58
NO
YES
MESSAGE "MECHANICAL FAULT"
60
MESSAGE "STARTING DEVICE OK"
59
RETURN

Fig. 3

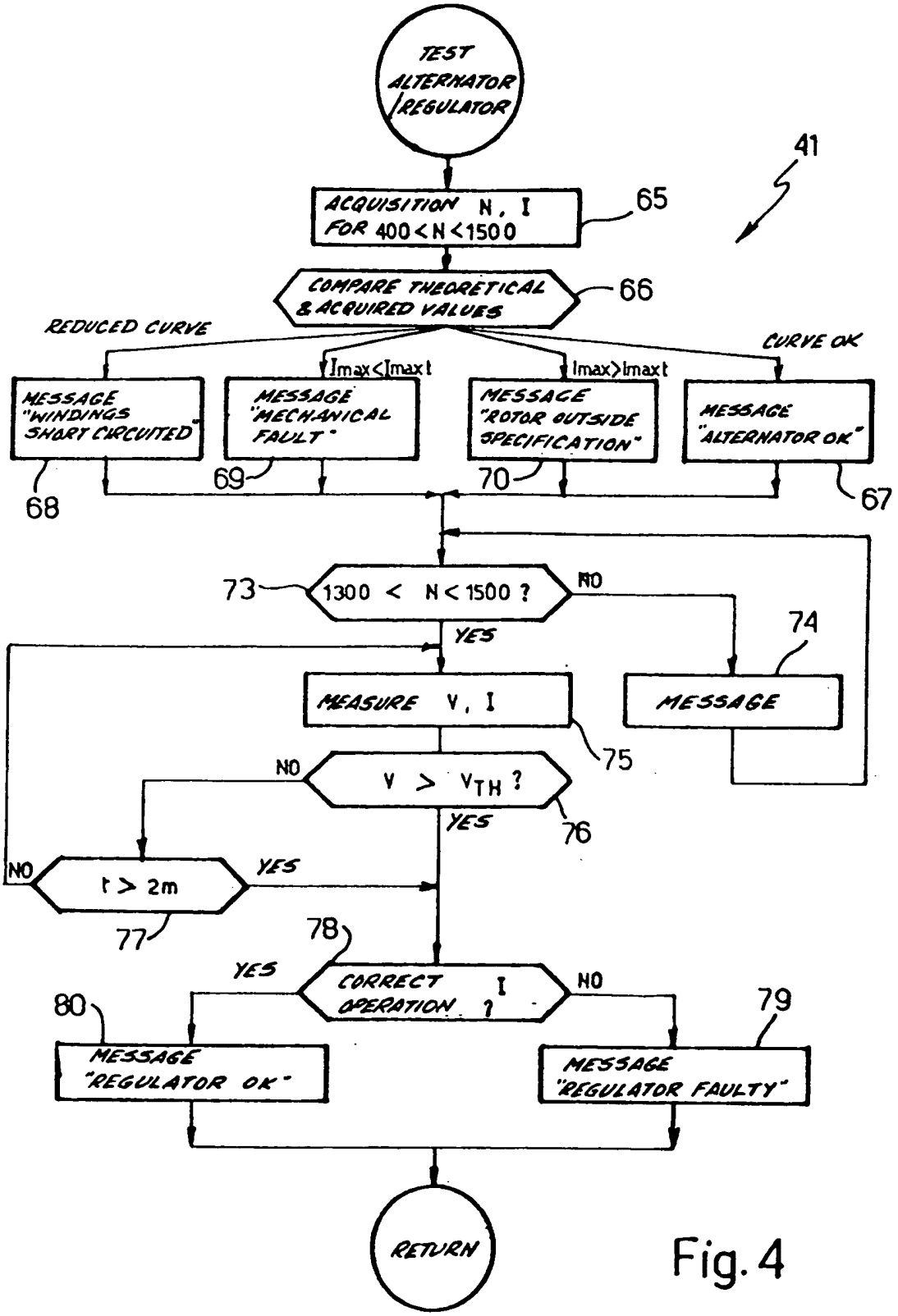
TEST ALTERNATOR REGULATOR
41
ACQUISITION N, I FOR 400<N<1500
65
COMPARE THEORETICAL & ACQUIRED VALUES
66
REDUCED CURVE
Imax<Imaxt
Imax>Imaxt
CURVE OK
MESSAGE "WINDINGS SHORT CIRCUITED"
MESSAGE "MECHANICAL FAULT"
MESSAGE "ROTOR OUTSIDE SPECIFICATION"
MESSAGE "ALTERNATOR OK"
68
69
70
67
73
1300 < N < 1500 ?
NO
YES
74
MEASURE V, I
MESSAGE
75
NO
V > VTH ?
YES
76
NO
t > 2m
YES
77
78
YES
CORRECT I OPERATION ?
NO
80
79
MESSAGE "REGULATOR OK"
MESSAGE "REGULATOR FAULTY"
RETURN

Fig. 4

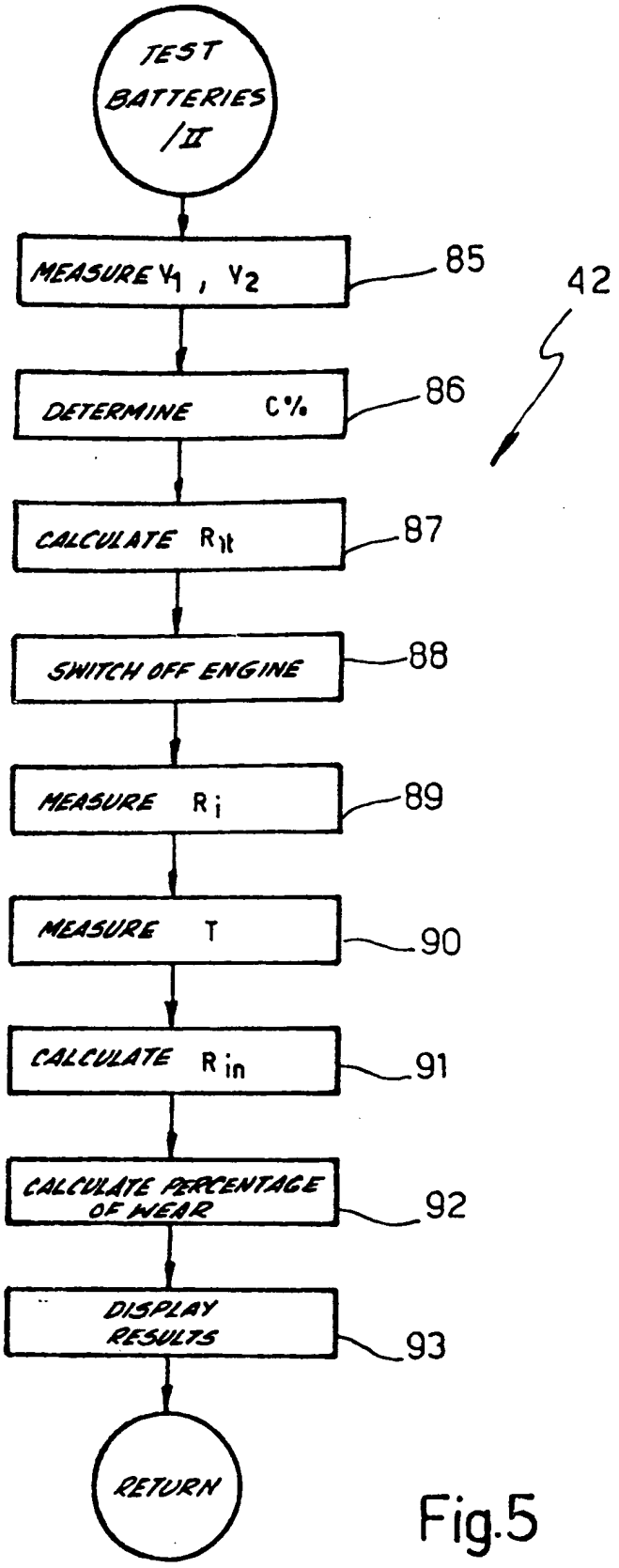
TEST BATTERIES /II
MEASURE V_1 , V_2
85
42
DETERMINE C%
86
CALCULATE R_{it}
87
SWITCH OFF ENGINE
88
MEASURE R_i
89
MEASURE T
90
CALCULATE R_{in}
91
CALCULATE PERCENTAGE OF WEAR
92
DISPLAY RESULTS
93
RETURN

Fig.5

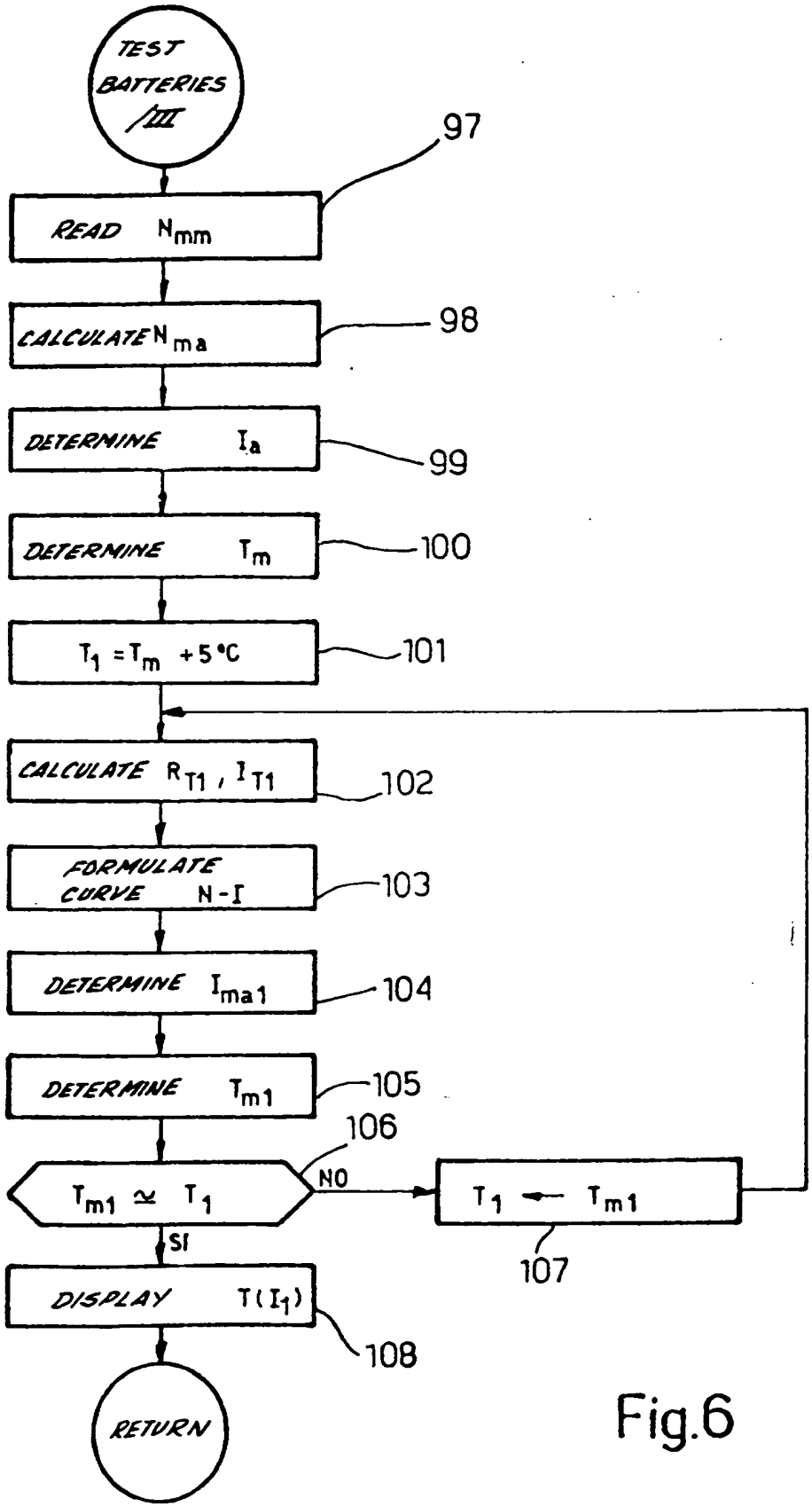
TEST BATTERIES /III
97
READ N_{mm}
98
CALCULATE N_{ma}
99
DETERMINE I_a
100
DETERMINE T_m
101
$T_1 = T_m + 5°C$
102
CALCULATE R_{T1}, I_{T1}
103
FORMULATE CURVE N-I
104
DETERMINE I_{ma1}
105
DETERMINE T_{m1}
106
$T_{m1} \simeq T_1$
NO
$T_1 \leftarrow T_{m1}$
107
SI
DISPLAY $T(I_1)$
108
RETURN

Fig.6

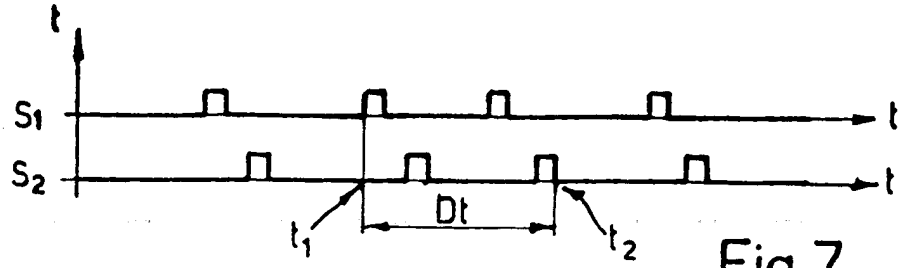

Fig.7

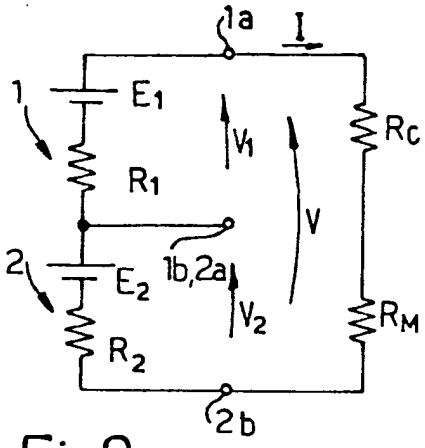

Fig.8

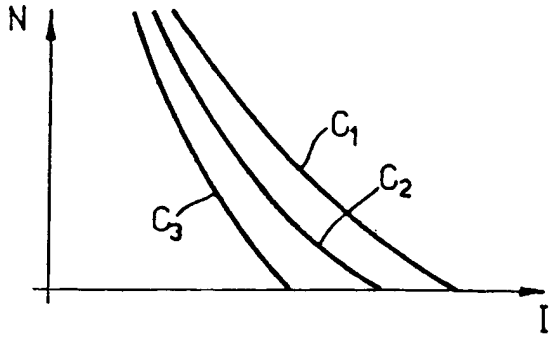

Fig.9

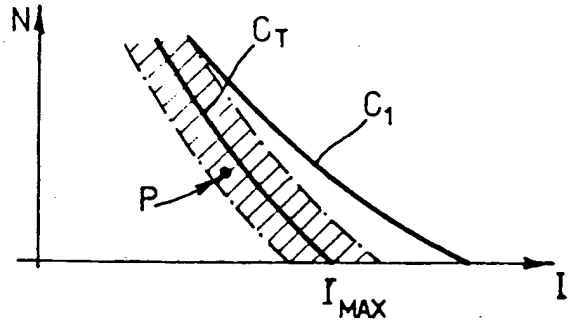

Fig.10

Fig.11

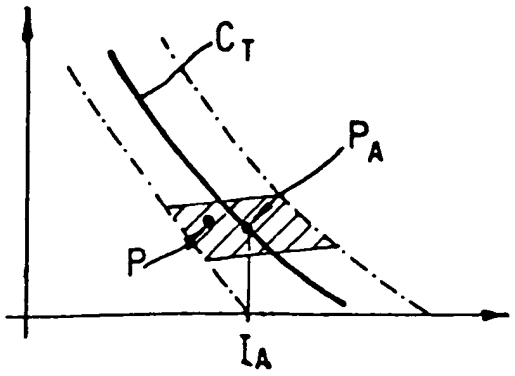

Fig.12

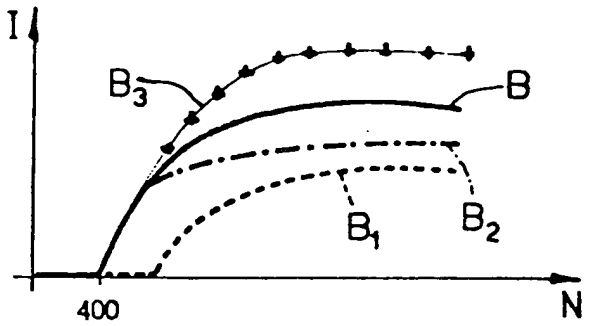

Fig.13

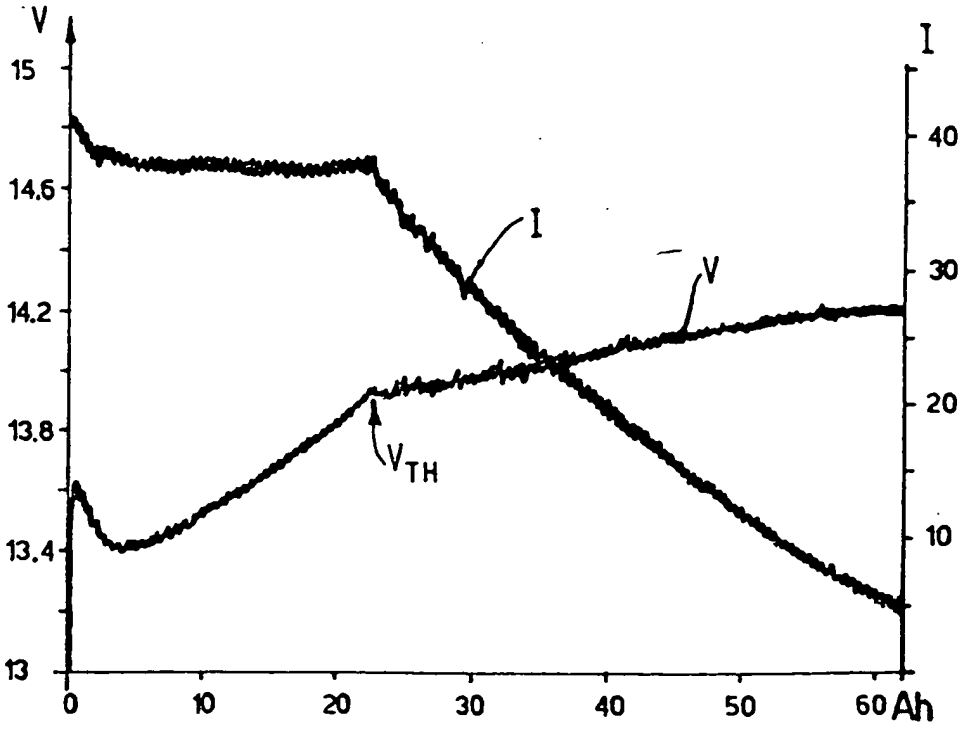

Fig.14

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 5921

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	WO-A-90 04188 (ALLIED-SIGNAL) * page 28 - page 31 *	1,15,16	G01R31/00
A	DE-A-38 08 559 (HELLA)		

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

G01R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 January 1994	Hoornaert, W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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